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Singular vector growth in different flow regimes of the differentially heated rotating annulus

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In the absence of easily observed natural systems resembling the atmosphere, the differentially heated rotating annulus laboratory experiment had been designed as an analogue to atmospheric flows. In contrast to the atmosphere, such rotating annulus experiments are controllable and reproducible. We use a low-order model of this experiment as well as new laboratory data to determine singular vectors in different flow regimes. Usually, such regimes are characterized by the typical spatial structure of the most unstable linear mode. However, there where also attempts to characterize the regimes and their transitions by using other measures, like Lyapunov exponents. These appeared to be more useful in particular when the annulus flow becomes turbulent.

We show that singular vector growth rates can also be used to characterize the flow regimes of the low-order model. Whether this holds also for the flow regimes of the real laboratory experiment is not clear yet. However, we show that the low-order model captures many features of the real flow. Moreover, we compute singular vectors empirically from the laboratory data and compare them with the singular vectors of the low-order model. Again, a qualitative agreement can be found. This comparison gives us confidence that the results obtained for the low-order model can be transferred to the laboratory experiment and the real atmosphere.

Our study might help to understand better the role of optimal perturbations in quasigeostrophic turbulence.